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ABSTRACT

Described is the use of the computer model "BUFLO." BUFLO is a simulation which allows students to study the historical and biological reasons for the extinction of the buffalo. BUFLO simulates the natural life cycle of the buffalo and allows the student to manipulate harvesting policies to reach certain goals outlined in the student handbook. (Author/RE)

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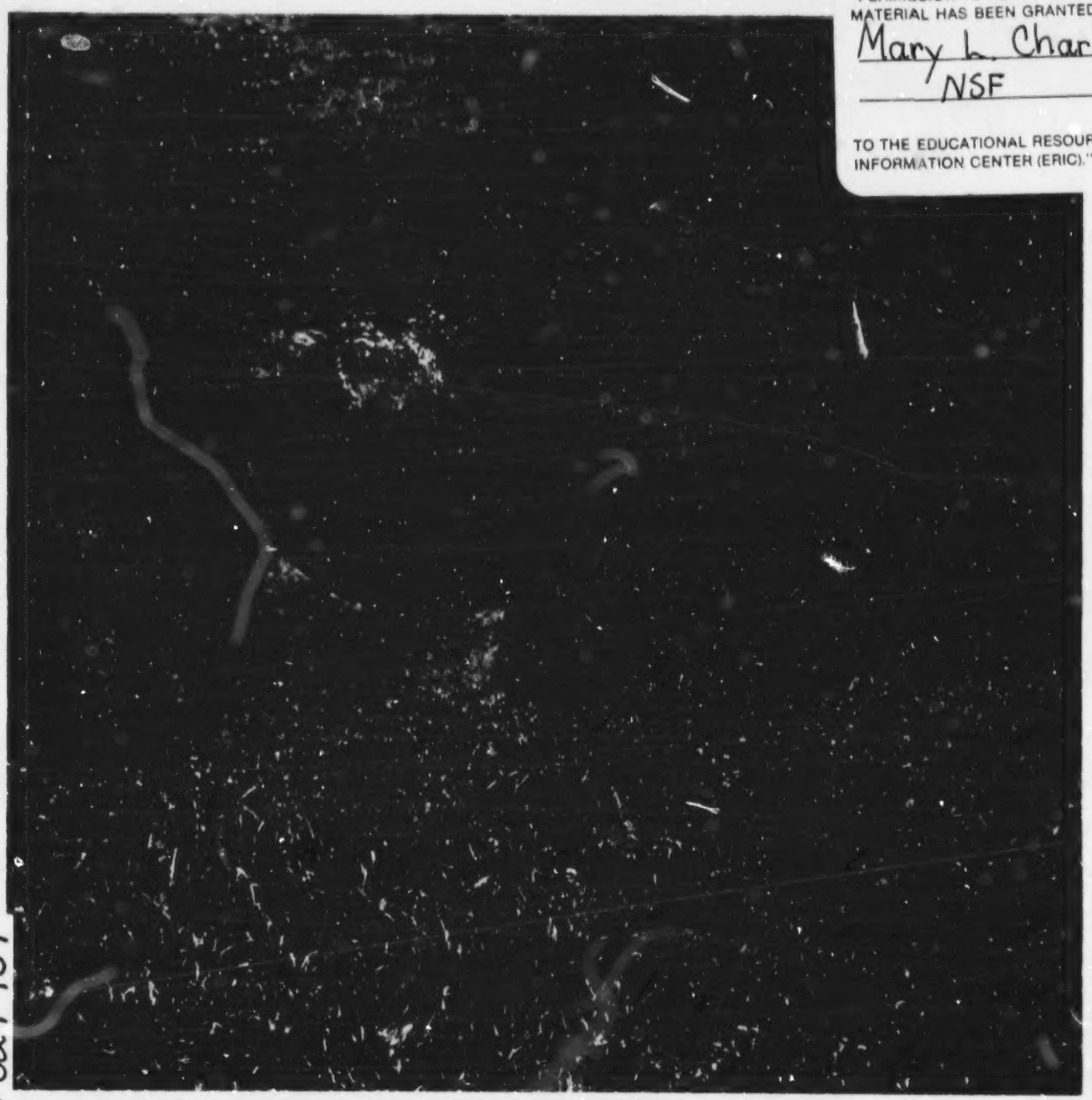

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STUDENT MANUAL

BUFLO

BUFFALO HERD POPULATION MANAGEMENT

HUNTINGTON TWO COMPUTER PROJECT

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BUFLO

STUDENT MANUAL

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I. INTRODUCTION TO *BUFLO*

The North-American bison, commonly, but incorrectly, called the buffalo, or Plains buffalo, once existed in enormous herds on the prairies of Western Canada and the United States. Estimates of the population in 1830 range from 30 million to over 100 million, with 60 million being a reasonable compromise. This is the greatest aggregation of large animals known to civilized man.

We may obtain an appreciation of the size of the natural resource represented by these vast herds by looking at their biomass. At an average weight of 1,000 pounds (some bulls exceed 2,000 pounds), 60 million buffalo represent a biomass of 60 billion pounds, compared to a biomass of less than 30 billion pounds for the present human population of the United States.

From another viewpoint, the destruction of these animals represented the loss of a potentially major source of meat protein. A single buffalo could have provided the entire meat supply for five people for one year.

The carnage seems more senseless when we explore the reasons for killing the buffalo. The prime motivation appeared to be the sale of buffalo hides, with the meat left to rot. A single hunter slaughtered from 20 to over 100 buffalo in a day, depending upon his luck and the number of skinners he had working for him. He would only shoot as many as could be skinned that day, since wolves and coyotes would tear the hides of any left over. Of these hides, over two thirds spoiled before they reached the tannery!

Most hunters left the carcasses to the wolves, but a few pickled the tongues and parts of the hump and haunches for shipment East -- a harvest of only 50 pounds of meat from an animal weighing over 1,000 pounds.

The destruction of female buffalo from the 1830's to the 1890's was a particularly tragic aspect of our history. Three quarters of the buffalo killed were females. Perhaps this was because their meat was more tender, or their hides more desirable, or because they easier to catch. In any case, when a female buffalo was killed so was the potential for her to produce as many as 30 offspring.

The peak slaughter was reached in 1872 when national heroes like "Buffalo Bill" Coty led the killing of more than 7 million buffalo. By 1887, only 200 buffalo were left and, finally, conservationists were permitted to save these survivors from extinction. The few thousand buffalo which roam in protected areas of the Western United States are descendants of these survivors.

In this *STUDENT MANUAL* you will investigate the consequences of various harvesting policies that might have been used to conserve this valuable resource. Could a large yield in buffalo products have been obtained without driving this species to the brink of extinction?

In order to plan your harvesting policies, it is important to understand something of the life cycle of the buffalo. Calves are born in the spring; they are dependent on their mothers for the entire first year of their life. The calf is able to stand up in 3 or 4 days and both the calf and its mother are then able to rejoin the herd.

Buffalo older than one year, but younger than two, are called yearlings. They are able to live without their mothers, but they rely on the adults for protection.

In the buffalo's third year, it is considered an adult. Nearly all adults take part in the mating that occurs in August or early September. Buffalo are polygamous, so one male will mate with several females. The maximum number of matings that a male can participate in is about 10.

Traditionally, the hunting of buffalo took place from the melting of the spring snow until the weather became harsh in the fall. When you set a harvest quota, the *BUFLO* computer program assumes that the harvest will be carried out within this time period.

The *BUFLO* program uses several abbreviations and symbols to stand for the different ages and sexes in a buffalo herd. The table below will help you to understand them.

GROUP	ABBREVIATION	GRAPH SYMBOL
Adult Males	AM	A
Adult Females	AF	
Yearling Males	YM	Y
Yearling Females	YF	
Calf Males	CM	C
Calf Females	CF	

II. COMPUTER LABORATORY GUIDE

There are two general types of investigations possible using *BUFLO*. *PART I* investigates both short and long-range effects of different harvesting (hunting) policies for their effect on the size and make-up of the buffalo herd. In *PART II*, which begins on p.14, *BUFLO* can be used to design alternative strategies for achieving certain goals in herd size and growth.

PART I: INVESTIGATING THE EFFECTS OF SPECIFIC HARVESTING POLICIES

The buffalo hunters slaughtered all the buffalo they saw, no matter what the age or sex of the animals. This resulted in the near extermination of the millions of these animals that once roamed the entire country. Could the buffalo hunters still have harvested their meat and hides without destroying the buffalo? You will investigate this question by examining the effect of harvesting adult buffalo of a single sex.

A. DETERMINE THE EFFECTS OF HARVESTING ONLY ADULT MALES OVER A FIVE-YEAR PERIOD.

Your objective is to determine how many buffalo can be harvested over the five-year period without lowering the total herd population.

INFORMATION ON INITIALIZATION OF THE MODEL -- PROCEED AS FOLLOWS:

You will be asked to choose a policy of herd management, either (1) total freedom of herd control, or (2) automatic safeguards for herd population.

- Select total freedom of herd control (choice 1).

You will then be asked "YEARS FOR OBSERVE, CHANGE POLICY, REPORT?". Respond by typing 3 numbers separated by commas. The first number specifies the number of years that you wish to study the buffalo herd. The second and third numbers specify how often you wish to change the harvesting policy and obtain population reports.

- Choose to observe the population for 5 years. Keep your harvesting policy the same over the 5-year period and obtain a population report each year. When the computer asks for "YEARS FOR OBSERVE, CHANGE POLICY, REPORT?" type 5,5,1.

Next you will be asked carrying capacity.

- Set the carrying capacity equal to 40 million. This is the largest number of buffalo that the winter range can support. Enter this number by typing 40E6 when the computer asks for carrying capacity.

- Select any starting year -- 1860, for example.

- Initialize the buffalo by total herd. This is choice 2. For your first few runs, initialize by total herd rather than by breakdown.

- Set the total herd size to 20 million. This can be done by typing 20E6.

Next you will set a quota. The "quota" is the maximum amount of buffalo you choose to harvest.

- Set a harvest quota for adult males only. They are symbolized by "AM." The computer will print:

  A AM 7560000 ?

  7560000 is the total number of adult male buffalo, the question mark (?) is asking how many of the adult males do you want to harvest each yesr? Harvest enough males to keep the herd size near 20 million. You may need to make several runs to get this herd size.

On the right side of the page, a graph is printed under the heading: "PERCENTAGE OF ORIGINAL POPULATION". You may consult this graph to see changes at a glance. The change in the adult population is symbolized by the letter A. Yearlings are symbolized by Y, and calves by C. If the mark moves to the right, the population is rising. As it moves to the left, the population is falling.

- Enter your most successful run on the data sheet found on the next page.

Name _____

HARVESTING ADULT MALES ONLY (FIVE-YEAR PERIOD)

CARRYING CAPACITY = 40E6

YEARS FOR:
OBSERVE, CHANGE POLICY, REPORT: 5 , 5 , 1

Initial herd size = _____

Harvesting Policy:

Adult males only: _____ per year

Total harvest over five-year period: _____

Fill in chart below using your most successful attempt.

Group	Symbol	Starting Population	Final Population	Change over five years
Adult Males	AM			
Adult Females	AF			
Yearling Males	YM			
Yearling Females	YF			
Calf Males	CM			
Calf Females	CF			
Total Herd Population				

Conclusions: _____

B. DETERMINE THE EFFECTS OF HARVESTING ADULT MALES ONLY, OVER A 25-YEAR PERIOD (LONG TERM).

> Often it is possible to have a harvesting policy work over a short period, but cause serious harm over a longer period of time. Is this the case with harvesting the male buffalo? Again, harvest as many as possible without lowering the total population below 20 million.

Proceed as you did on the 5-year study, with the following changes:

> Observe population over 25 years and do not change harvesting policy over the 25-year period. Obtain population reports every 5 years. This can be done by entering 25,25,5 for OBSERVE, CHANGE POLICY, REPORT?

Remember you are to keep all other factors the same as in the first investigation. Your goal is to get the maximum harvest for the buffalo hunters and yet not to lower the total population of the herd.

Collect your final results using the data sheet on the next page.

Name _____

HARVESTING ADULT MALES ONLY (25-YEAR PERIOD)

CARRYING CAPACITY = 40E6

YEARS FOR:
OBSERVE, CHANGE POLICY, REPORT: 25 , 25 , 5

Initial herd size = _____

Harvesting Policy:

Adult males only: _____ per year

Total harvest over 25-year period _____

Fill in chart below using your most successful attempt.

Group	Symbol	Starting Population	Final Population	Change over 25 years
Adult Males	AM			
Adult Females	AF			
Yearling Males	YM			
Yearling Females	YF			
Calf Males	CM			
Calf Females	CF			
Total Herd Population				

Conclusions: _____

C. DETERMINE EFFECT OF A HARVESTING POLICY IN WHICH ONLY ADULT FEMALES ARE HARVESTED.

Carry out both a 5-year and a 25-year study similar to the previous two investigations EXCEPT you will attempt to maintain a constant population by harvesting *ADULT FEMALES ONLY*. *BUFLO* symbolizes Adult Female by AF.

When you obtain a satisfactory result, record your results on the appropriate data sheet on the following page and answer the following questions:

1) If you were a buffalo hunter interested in the continuance of the herd, would you harvest males or females?

2) Why is there a difference between harvesting males and females?

Name _____

HARVESTING ADULT FEMALES ONLY (FIVE-YEAR PERIOD)

CARRYING CAPACITY = 40E6

YEARS FOR:
OBSERVE, CHANGE POLICY, REPORT: 5 , 5 , 1

Initial herd size = _____

Harvesting Policy:

Adult females only: _____ per year

Total harvest over 5-year period _____

Fill in chart below using your most successful attempt.

Group	Symbol	Starting Population	Final Population	Change over five years
Adult Males	AM			
Adult Females	AF			
Yearling Males	YM			
Yearling Females	YF			
Calf Males	CM			
Calf Females	CF			
Total Herd Population				

Conclusions: _____

Name _____

HARVESTING ADULT FEMALES ONLY (25-YEAR PERIOD)

CARRYING CAPACITY = 40E6

YEARS FOR:
OBSERVE, CHANGE POLICY, REPORT: 25 , 25 , 5

Initial herd size = _____

Harvesting Policy:

Adult females only: _____ per year

Total harvest over 25-year period _____

Fill in chart below using your most successful attempt.

Group	Symbol	Starting Population	Final Population	Change over 25 years
Adult Males	AM			
Adult Females	AF			
Yearling Males	YM			
Yearling Females	YF			
Calf Males	CM			
Calf Females	CF			
Total Herd Population				

Conclusions: _____

D. DETERMINE THE EFFECTS OF HARVESTING BOTH ADULT MALES AND ADULT FEMALES OVER 5- AND 25-YEAR PERIODS.

As a buffalo hunter, you would be interested in obtaining the maximum yield of buffalo. So far we have examined the case in which the hunter is restricted to a certain sex. Would it be possible to get even higher yields by hunting both sexes, and still not lower the total herd size?

Your objective is to design a hunting policy that will obtain a maximum harvest over 5 or 25 years. You may harvest any number of males and any number of females.

Here are some ideas on how to proceed:

Select to have total freedom of herd control.

If you want the option of changing policy every year, type "1" for the second number, when the computer asks: "YEARS FOR OBSERVE, CHANGE POLICY, REPORT?" If you want to keep your policy the same over the entire period, use the same numbers as in previous investigations.

Set the carrying capacity equal to 40 million (40E6). Initialize by total herd and set the total herd size to 20 million (20E6).

Record your most successful attempts on the data sheets on the following pages. You should find it helpful to consult the graph on the right side of the printout.

Name _____

HARVESTING BOTH ADULT MALES AND FEMALES OVER A FIVE-YEAR PERIOD

CARRYING CAPACITY = 40E6

YEARS FOR:
OBSERVE, CHANGE POLICY, REPORT: 5 , ____ , ____

Initial herd size = _____

Harvesting Policy: (Describe in space below the policy that produced the maximum harvest without lowering the total herd size.)

_____

_____

_____

Total harvest over 5-year period _____

Group	Symbol	Starting Population	Final Population	Change over five years
Adult Males	AM			
Adult Females	AF			
Yearling Males	YM			
Yearling Females	YF			
Calf Males	CM			
Calf Females	CF			
Total Herd Population				

Conclusions: _____

_____

_____

_____

Name _____

HARVESTING BOTH ADULT MALES AND FEMALES OVER A 25-YEAR PERIOD

CARRYING CAPACITY = 40E6

YEARS FOR:
OBSERVE, CHANGE POLICY, REPORT: 25 , ____ , ____

Initial herd size = _____

Harvesting Policy: (Describe in space below the policy that produced the maximum harvest without lowering the total herd size.)

_____

_____

_____

Group	Symbol	Starting Population	Final Population	Change over 25 Years
Adult Males	AM			
Adult Females	AF			
Yearling Males	YM			
Yearling Females	YF			
Calf Males	CM			
Calf Females	CF			
Total Herd Population				

Conclusions: _____

_____

_____

_____

PART II: INVESTIGATING ALTERNATIVE STRATEGIES FOR ACHIEVING CERTAIN POPULATION EFFECTS

Today man is faced with preserving the buffalo that have escaped extinction. People concerned with regulating the number of wild game animals are called game managers. They must be concerned both with the preservation and welfare of the animals in their care. Unfortunately, game managers cannot permit the buffalo to reproduce without limit because most of the buffalo's natural habitat has been destroyed. Without human control, the buffalo would soon run out of food and range.

In the investigations below, you will take on the role of a game manager with a certain problem. You will be asked to devise ways of obtaining desired results. You will test your proposed solutions using *BUFLO*.

A. SUPPOSE THAT A GAME MANAGER WISHES TO MAINTAIN THE SIZE OF HIS PRESENT HERD OF 26,000 BUFFALO.

1) Think of several alternatives he has for achieving this goal. (Remember he can change his policy from year to year.)

a) _____

_____

_____

b) _____

_____

_____

c) _____

_____

_____

2) Explore each of your proposals for a period of at least 20 years. Assume a carrying capacity of 80 thousand (8E5).

3) Prepare your own data sheets to record the results of your simulations.

B. SUPPOSE YOU WISH TO DOUBLE THE PRESENT SIZE OF THE HERD OVER A PERIOD OF 20 YEARS. (ASSUME THE PRESENT SIZE TO BE 26000; CARRYING CAPACITY 800000.)

1) State some alternative strategies:

a) _____

_____

_____

b) _____

_____

_____

c) _____

_____

_____

2) Explore each of your above alternatives for a period of at least 20 years.

3) Prepare data sheets to describe the results of your simulations.

C. DEVELOP AND EXPERIMENT WITH SOME STRATEGIES FOR MAINTAINING THE FEMALE:MALE RATIO AT 3:2.

1) _____

_____

_____

_____

2) _____

_____

_____

_____

3) _____

_____

_____

_____

III. ADDITIONAL INVESTIGATION SUGGESTIONS

Design your own investigations to answer the following questions:

1) What happens to a buffalo herd initialized above the carrying capacity?

2) How many years will it take to totally eliminate a herd of 20 million buffalo, if you:

   a) Kill all adults every year?

   b) Kill all yearlings every year?

   c) Kill all calves every year?

3) Is it necessary to kill every buffalo in order to cause extinction?

4) What is the minimum number of males and females needed to start a growing population?

5) Is there a minimum male-to-female ratio required for high fertility?

NOTE: THE ABOVE QUESTIONS MAY NOT HAVE A SINGLE CORRECT ANSWER. THE PARTICULAR ANSWER WILL DEPEND ON THE WAY YOU SET UP YOUR INVESTIGATION. REMEMBER TO KEEP COMPLETE AND ACCURATE RECORDS.

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TEACHER MANUAL

BUFLO

BUFFALO HERD POPULATION MANAGEMENT

Developed by:

Ludwig Braun, State University of New York
Stony Brook, New York
James Friedland, Douglas MacArthur High School
Levittown, New York

Programmed by:

Burt Esrig, State University of New York
Stony Brook, New York
Michael Weisner, State University of New York
Stony Brook, New York
Ludwig Braun
James Friedland

Illustrations by:

Marie Rulon, State University of New York
Stony Brook, New York

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BUFLO

TEACHER MANUAL

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I. BASIC INFORMATION ABOUT THE UNIT

Subject Area: Science, Social Studies

Specific Topic: A Simulation of the Ecology of the North-American Bison (Buffalo)

Grade Level: 7 - 12

Coordinated Computer Program: *BUFLO*

Computer Language: BASIC

Special Language Features Used: TAB, FNA(X)

Abstract: *BUFLO* is a computer-assisted simulation which allows students to study the historical and biological reasons for the extinction of the buffalo. The *BUFLO* model simulates the natural life cycle of the buffalo and allows the student to manipulate harvesting policies in order to reach certain goals that are outlined in the *STUDENT MANUAL*.

The *TEACHER MANUAL* and *RESOURCE MANUAL* provide the necessary background for student guidance and evaluation. Details on model construction will be found in the *RESOURCE MANUAL*.

II. WHY USE *BUFLO*?

The study of ecological systems has become an increasingly relevant and important part of science education at the secondary school level. Studying past events and present consequences with regard to mismanagement of resources, however, does not allow the student any latitude for asking and answering the "what if" questions. Limitations of time, space and resources prohibit actual experimentation, but computer simulation provides an environment in which the "what if" questions can be explored and answered. In addition, *BUFLO* will help the student gain a better understanding of man/machine cooperation in problem solving. His experience with this simulation program will permit exploration of "what if" questions, and will allow him to experiment with policies which might prove disastrous in real life. Simulations such as this actually are useful in formulating decisions on harvesting policies.

III. USING *BUFLO* WITH YOUR CLASS

BUFLO is an ideal exercise for the teacher having access to only one teletype. Assign each group of students a problem from the *STUDENT MANUAL*. The Manual contains plan sheets so students may prepare their investigation before class. Then, after all groups have carried out their unique investigation, have them report their findings to the class as a whole.

Here is one possible format that some teachers have found successful. Have the class play the role of a Congressional Investigation Committee in the year 1830, looking into the possibility of establishing a conservation act for protecting the buffalo. Groups within the Committee have been asked to research a proposal for harvesting buffalo. Inject a note of realism by introducing testimony from the buffalo-hunter interests. These arguments might be presented:

1) Washington is a long way from the Great Plains, and if the Committee passes a law which is too stiff, then the buffalo hunters will probably ignore it (and get away with it too!)

2) Buffalo skins are in demand in the East, and buffalo meat is needed for railroad construction crews in the West. Easterners are politically powerful and the railroad interests form a strong lobby. As elected representatives, the Committee members wouldn't want to lose office, so the chances for conservation reform is slim.

3) Since settlement is starting on the Great Plains, the buffalo cannot be allowed to grow in number because land is needed for farms.

These arguments and the suggestion that the Indians could be controlled if the buffalo were exterminated were actually used with great success during the mass slaughter of the buffalo in the 19th Century.

After the groups within the Committee report, have the Committee as a whole debate and reach a compromise solution. Then, test their solution using *BUFLO*.

Of course, the teacher having more than one teletype has this and many more options open to him. Look through the *STUDENT* and *TEACHER MANUALS* and let your experience and imagination guide you in the selection of an appropriate exercise.

A. Preparatory Activities

- Have your class investigate the life history of the buffalo. Materials in the *STUDENT* and *RESOURCE MANUALS* may serve this purpose.
- Define the term *carrying capacity* as the number of organisms (in this case, buffalo) that the environment is capable of maintaining from year to year.
- Explain to your class the mechanics of initializing *BUFLO* and inputting the harvesting quota. Many teachers have made overhead projections of a sample run for this purpose.
- Assumptions underlying the *BUFLO* model should be explained to the students. A list of these assumptions may be found in the *RESOURCE MANUAL*. These assumptions can be compared with the information learned about the biology of the buffalo. (See *RESOURCE MANUAL*, pp. 4-5.)

B. Evaluation and Follow-Up

- Encourage the spirit of inquiry and exploration by indicating there are no *right* or *wrong* answers to the student investigations. In a real sense, there are different solutions for each set of criteria.
- Discuss the alternative strategies for maintaining the buffalo herd. Have the students compare the advantages and disadvantages of each.
- Discuss why measures were not taken to protect the buffalo before it was almost too late.
- Ask the students if they can name any animals or plants that are now being threatened with extinction (timber wolf, bald eagle, mountain lion, etc.). Ask them to investigate what is being done to help protect these species. This approach may help them understand why very little was done to help protect the buffalo at the time.

IV. DESCRIPTION OF THE *BUFLO* PROGRAM

The first question *BUFLO* asks is:

HAVE YOU USED BUFLO BEFORE (1=YES, Ø=NO)?

By having the instructions dittoed ahead of time, or, by having the students refer to the COMPUTER LABORATORY GUIDE in the *STUDENT MANUAL* much time can be saved.

Next the program asks:

THERE ARE TWO POLICIES OF HERD MANAGEMENT AVAILABLE.
TOTAL FREEDOM OF HERD CONTROL (1)
OR AUTOMATIC SAFEGUARDS FOR HERD POPULATION (2)
WHICH POLICY DO YOU PREFER ?

If the student chooses (1), he will be allowed to continue to harvest under any circumstances. Choice (2) halts harvesting anytime the herd is placed in danger of extinction. But Choice (2) does not offer complete protection. If the harvesting is not carefully planned, the herd can still be destroyed.

Then the program will ask:

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?

This is the most difficult question in the program and you may have to help your students the first time they encounter it. A proper response consists of three numbers separated by commas. The first number represents the total number of years the herd is to be studied. For example, if the student wants to study the herd for ten years, the first number should be typed as "1Ø". The second number asks how often policy changes should be allowed. The number "1" means every year, "2" means every second year, and so on. So if the student wants to have the same policy over the entire period (10 years), he should ask for policy change every 10th year. This is done by typing "1Ø" for the second number. The third number asks how often the student wants population reports. If the student wants population reports every year, he would respond by typing "1" for the third number. So the student's response would look like:

1Ø,1Ø,1

(The *STUDENT MANUAL* is very specific on the proper response, so if your students carry out manual investigations, they should have little trouble.)

Next, the computer will type:

CARRYING CAPACITY?

Again, the *STUDENT MANUAL* guides the student in the selection of a proper number, but 40 million (written as 40E6 or 40000000) represents a realistic number for the middle 19th Century.

Then:

STARTING YEAR?

Any year number may be used. If the student types 1850, it means that he is starting his simulation in the year 1850.

WILL YOU INITIALIZE NUMBER OF BUFFALO BY
BREAKDOWN (1) OR TOTAL HERD (2) ?

Have the students select Choice (2). Then by typing in the total herd population, the computer will break the herd into Adult Males, symbolized as AM, Adult Females (AF), Yearling Males (YM), Yearling Females (YF), Calf Males (CM), and Calf Females (CF).

BUFLO will then print a heading similar to the one below:

```
                                                PERCENTAGE OF ORIGINAL POPULATION
SYM/GROUP    POP                 QUOTA          0          100          200          300
--------     ---                 -----          I----------I----------I----------I
SPRING OF  YEAR  1860                                        CYA
HERD SIZE + 20000000
A    AM     7560000                ?
A    AF     6760000                ?
Y    YM     1240000                ?
Y    YF      920000                ?
C    CM     1820000                ?
C    CF     1700000                ?
```

On the right, *BUFLO* prints a normalized graph. The total number of adults is plotted as "A", the yearlings as "Y" and the calves as "C". If two numbers have the same normalized value, the letters will be printed next to each other without a space between them.

On the left, *BUFLO* gives the Year, Total Herd Size, and a Population breakdown. Shown in the above sample is the breakdown of the Adult Males (AM). First the graph symbol A is printed, then the letters AM, then the population of the adult males, and finally a question mark.

The question mark is asking the student to set a harvesting quota. It essentially says, HOW MANY OF THE ADULT MALES SHOULD BE HARVESTED EACH YEAR? This question mark will appear for each population group in any year in which policy is to be changed. In this example the student might want to harvest ten thousand adult males. After the question mark he would type 10000 (remember no commas!).

At the end of the period of study, the computer prints:

TOTAL HARVEST FOR (T) YEARS IS (H) BUFFALO.

Consult annotated sample runs in the *RESOURCE MANUAL* for more information.

V. TEACHER KEY TO *STUDENT MANUAL* INVESTIGATIONS

The *STUDENT MANUAL* is divided into two sections. *PART I* investigates historical aspects of the buffalo slaughter in the 19th Century. Students investigate the question "Could large numbers of buffalo have been harvested without driving this species to the edge of extinction?"

A. DETERMINE THE EFFECTS OF HARVESTING ADULT MALES OVER A FIVE-YEAR PERIOD.

Students will be surprised to find out that large numbers of adult males can be harvested with very little lowering of the population. Buffalo, being polygamous, require a relatively small number of males to produce the next generation.

In the following sample run, the student has harvested 1,300,000 male buffalo per year over a 5-year period. This produces a total harvest of 6.5 million.

```
                BUFFALO HERD MANAGEMENT

HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO) ?1

WHICH POLICY DO YOU PREFER ?1

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?5,5,1

CARRYING CAPACITY ?40E6

STARTING YEAR= ?1830

WILL YOU INITIALIZE NUMBER OF BUFFALO BY
BREAKDOWN (1) OR TOTAL HERD (2) ?2
TOTAL BUFFALO IN HERD ?20E6
```

SYM/GROUP	POP	HARVEST QUOTA
SPRING OF YEAR 1830		
HERD SIZE= 20000000		
A AM	7560000	?1300000
A AF	6760000	??
Y YM	1240000	??
Y YF	920000	??
C CM	1820000	??
C CF	1700000	??
SPRING OF YEAR 1831		
HERD SIZE= 23191107		
A AM	6563000	
A AF	6773000	
Y YM	1902000	
Y YF	1820000	
C CM	2465377	
C CF	2275730	
SPRING OF YEAR 1832		
HERD SIZE= 19993822		
A AM	5556503	
A AF	6361508	
Y YM	1479226	
Y YF	1365433	
C CM	2460100	
C CF	2270861	
SPRING OF YEAR 1833		
HERD SIZE= 19760297		
A AM	4940356	
A AF	7190516	
Y YM	1476060	
Y YF	1362517	
C CM	2486561	
C CF	2225287	
SPRING OF YEAR 1834		
HERD SIZE= 19788503		
A AM	4383364	
A AF	7591451	
Y YM	1401937	
Y YF	1377172	
C CM	2617331	
C CF	2416528	
SPRING OF YEAR 1835		
HERD SIZE= 19941374		
A AM	3833379	
A AF	7784183	
Y YM	1573789	
Y YF	1442059	
C CM	2726381	
C CF	2516383	

TOTAL HARVEST IN 5 YEARS IS 6500000 BUFFALO.

PERCENTAGE OF ORIGINAL POPULATION

0 I---------- 100 I---------- 200 I---------- 300 I

CYA

AY C

A YC

A YC

A YC

A YC

B. DETERMINE THE EFFECTS OF HARVESTING ADULT MALES OVER A 25-YEAR PERIOD (LONG TERM).

The same effect as noted in Section A will be seen in this investigation. In fact, even larger yearly harvests are possible, if the student is willing to place the herd in the precarious position of very few males and many females.

The following run has been condensed to fit a single page.

```
          BUFFALO HERD MANAGEMENT

HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO) ?1

WHICH POLICY DO YOU PREFER ?1

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?25,25,5

CARRYING CAPACITY ?40E6

STARTING YEAR= ?1830

WILL YOU INITIALIZE NUMBER OF BUFFALO BY
BREAKDOWN (1) OR TOTAL HERD (2) ?2
TOTAL BUFFALO IN HERD ?20E6

                        HARVEST        PERCENTAGE OF ORIGINAL POPULATION
SYM/GROUP  POP           QUOTA      0            100           200           300
---------  ---           -----      I------------I------------I------------I
SPRING OF YEAR  1830                                CYA
HERD SIZE= 20000000
A  AM  7560000          ?1460000
A  AF  6760000          ?0
Y  YM  1240000          ?0
Y  YF  920000           ?0
C  CM  1820000          ?
;;TTY24: - HI!
0
C  CF  1700000          ?0

SPRING OF YEAR  1835                          A        YC
HERD SIZE= 19420033
A  AM  3284711
A  AF  7796734
   YM  1583335
      1561540

SPRING OF YEAR  1855                                   A              YC
HERD SIZE= 31756001
A  AM  3739132
A  AF  14751059
Y  YM  2570604
Y  YF  2372866
C  CM  4327617
C  CF  3994723

 TOTAL HARVEST IN 25 YEARS IS 36725000 BUFFALO.
```

C. DETERMINE EFFECT OF A HARVESTING POLICY IN WHICH ONLY ADULT FEMALES ARE HARVESTED.

The students will discover that females are far more important to population maintenance than males. Below are condensed RUNS of both 5-year and 25-year investigations:

5-YEAR STUDY

```
                BUFFALO HERD MANAGEMENT

HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO) ?1

WHICH POLICY DO YOU PREFER ?1

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?5,5,1

CARRYING CAPACITY ?4056

STARTING YEAR= ?1830

WILL YOU INITIALIZE NUMBER OF BUFFALO BY
BREAKDOWN (1) OR TOTAL HERD (2) ?2
TOTAL BUFFALO IN HERD ?2056

                          HARVEST        PERCENTAGE OF ORIGINAL POPULATION
SYM/GROUP  POP             QUOTA      0            100           200           300
---------  ---             -----      |------------|------------|------------|
SPRING OF YEAR  1830                                CYA
HERD SIZE= 2333333
A  AM  7563333             ?3
A  AF  6763333             ?400000
Y  YM  1243333             ?0
Y  YF  333333              ?3
C  CM  1833333             ?0
C  CF  1733333             ?0

SPRING OF YEAR  1831
HERD SIZE= 20537643
                ?0

SPRING OF YEAR  1835                                AYC
HERD SIZE= 10833950
A  AM  8888872
A  AF  5759861
Y  YM  1131134
Y  YF  1044179
C  CM  1081535
C  CF  1029102

 TOTAL HARVEST IN 5 YEARS IS 2333333 BUFFALO.
```

BUFFALO HERD MANAGEMENT

25-YEAR STUDY

HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO) ?1

WHICH POLICY DO YOU PREFER ?1

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?25,25,5

CARRYING CAPACITY ?4E6

STARTING YEAR= ?1830

WILL YOU INITIALIZE NUMBER OF BUFFALO BY
BREAKDOWN (1) OR TOTAL HERD (2) ?2
TOTAL BUFFALO IN HERD ?2E6

SYM	GROUP	POP	HARVEST QUOTA	0	PERCENTAGE OF ORIGINAL POPULATION 100	200	300
SPRING OF YEAR 1830					C/O		
HERD SIZE= 2000000							
A	AM	7563333	?0				
A	AF	6763333	?2000000				
Y	YM	1243333	?0				
Y	YF	923333	?0				
C	CM	1823333	?0				
C	CF	1703333	?0				
SPRING OF YEAR 1835					A/C		
HERD SIZE= 21836817							
A	AM	8238403					
A	AF	6339473					
Y	YM	1237643					
Y	YF	1142437					
C	CM	2151795					
C	CF	1986272					
SPRING OF YEAR 1840					A/C		
HERD SIZE= 21138495							
A	AM	8622409					
A	AF	6180175					
Y	YM	1204322					
Y	YF	1111682					
C	CM	2008305					
C	CF	1929512					
SPRING OF YEAR 1845							
HERD SIZE= 20888							
SPRING OF YEAR 1855					A/C		
HERD SIZE= 19868621							
A	AM	8565088					
A	AF	5538787					
Y	YM	1093142					
Y	YF	1099054					
C	CM	1934526					
C	CF	1758024					

TOTAL HARVEST IN 25 YEARS IS 7000000 BUFFALO.

SUMMARY -- You might want to do something similar with data from your class. The information on the chart below comes from the sample runs on the previous pages.

COMPARISON OF MALE AND FEMALE HARVESTING POLICIES AIMED AT A CONSTANT POPULATION

5-YEAR PERIOD	QUOTA (kill/year)	HARVEST
Males only	1.3 million	6.5 million
Females only	400 thousand	2 million

25-YEAR PERIOD	QUOTA (kill/year)	HARVEST
Males only	1.469 million	36.725 million
Females only	280 thousand	7 million

NOTE THAT MUCH LARGER HARVESTS WERE POSSIBLE WHEN TAKING MALES.

D. DETERMINE THE EFFECTS OF HARVESTING BOTH ADULT MALES AND ADULT FEMALES OVER 5-YEAR AND 25-YEAR PERIODS.

This investigation is much more open. You may wish to restrict your students by instructing them to:

1) maintain the same harvesting policy over the entire period
2) maintain a certain harvesting ratio (such as 50-50)
3) receive reports at certain intervals

No sample runs are shown as there is no unique method of solution.

PART II of the *STUDENT MANUAL* is set in the framework of game management in the United States today. Students are given a buffalo herd and asked to design several strategies to reach a certain goal.

To ensure student success, encourage them to experiment with:

a) harvesting different ages
b) harvesting only in certain years
c) harvesting the sexes differently

To allow total freedom in investigation, students should have the option of changing policy every year. This can be done by responding to

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?

with a "1" in the second and third positions. So, if the student wants to investigate a 20-year period, he would type: 20,1,1

VI. WHAT CAN STUDENTS LEARN BY USING THIS UNIT?

After the student has completed a science unit centered around *BUFLO*, he should be able to:

1) Describe the effects of various harvesting policies.

2) Describe one harvesting strategy which would effect maintenance of the present buffalo population of 26,000.

3) Understand the reasons for limiting the number of doe which deer hunters are permitted to take in any single season.

4) Explain the limitations to which the model, and any predictions made with it, are subject.

5) Appreciate the value of careful management of our natural resources (e.g., whales, seals, forests, etc.).

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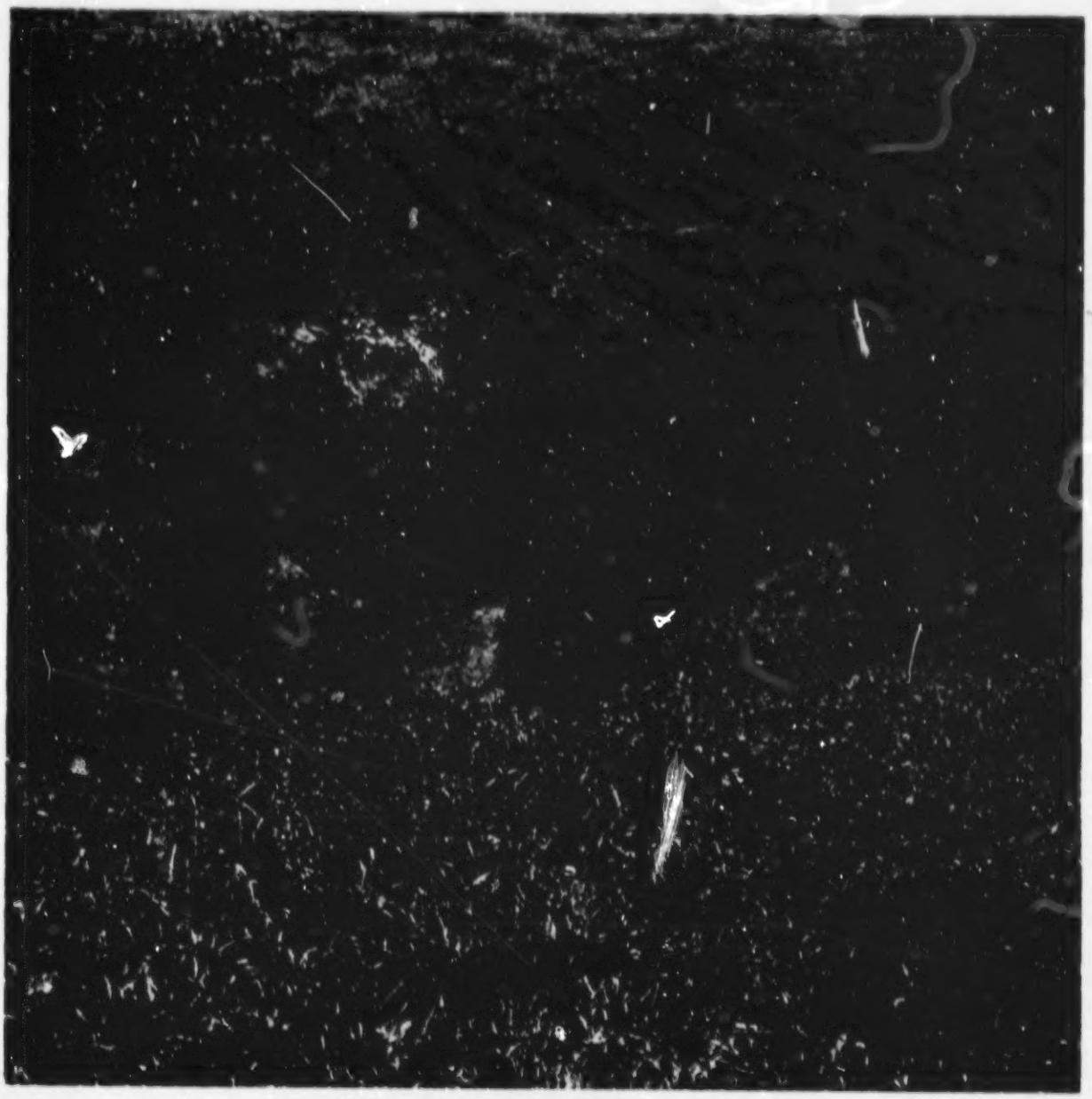

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RESOURCE MANUAL

BUFLO

BUFFALO HERD POPULATION MANAGEMENT

Developed by:

Ludwig Braun, State University of New York
Stony Brook, New York
James Friedland, Douglas MacArthur High School
Levittown, New York

Programmed by:

Burt Esrig, State University of New York
Stony Brook, New York
Michael Weisner, State University of New York
Stony Brook, New York
Ludwig Braun
James Friedland

Illustrations by:

Marie Rulon, State University of New York
Stony Brook, New York

HUNTINGTON TWO COMPUTER PROJECT

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RESOURCE MANUAL

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I. ABOUT THE BUFFALO

"BUFFALO" by Dick Pryce, *SCOUTING MAGAZINE**

In 1867, the Kiowa Indian Chief, Satanta, predicted the annihilation of the buffalo. Hardly anyone, white or red, took his warning seriously. Every spring a seemingly inexhaustible supply moved northward in the annual migration. Thousands upon thousands of buffalo would blacken the earth clear to the horizons. The Indians believed the buffalo were magically produced in limitless quantities in a gigantic cavern hidden somewhere in the vast reaches of the *Llano Estacado*, the semiarid Staked Plain region of Texas and New Mexico. The white man knew that the shaggy beasts always had been as numerous on the plains as countless blades of prairie grass. The immense tableland lying east of the Rocky Mountains, from Mexico to Canada, had always been one great big buffalo pasture.

A treaty was signed by the Plains Indians in which they agreed to abandon their free way of life, which included living on reservations and withdrawing all opposition to the railroads. In return, the peace commissioners promised annuities to feed and clothe the tribes and allowed them off-reservation hunting rights -- on lands the Indians had regarded as theirs for hundreds of years.

Railroad construction by the Union Pacific had reached Cheyenne, Wyoming by this time. The coming of the railroad heralded the beginning of the end to the American bison -- a name seldom if ever used by frontiersmen such as William F. Cody.

Cody was employed as a meat hunter for still another railroad, the Kansas Pacific. To feed the railroad's construction workers, in 17 months he killed nearly 4,300 buffalo, earning in the process $500 a month, the lifelong nickname of Buffalo Bill and a permanent niche in American history.

In 1868 the Kansas Pacific began selling tickets to sportsmen who would slaughter a few buffalo, then hop back on the train to return to the East. Some passengers didn't even leave their seats. They simply started banging away when the train passed through a herd. Nearly always the meat was left to rot. These senseless killings infuriated the Indians, and periodically they would vent their anger on small groups of white men. But aside from driving the herds back from the railroad rights-of-way, this merry diversion hardly seemed to dent the supply.

By this time the buffalo had been divided into what came to be called the Northern Herd and the Southern Herd, a trend that had been evident for years. The division apparently began in 1849, when tremendous numbers of men followed the Platte River of southern Nebraska westward toward the gold fields of California. At first these trailblazers could kill all the buffalo needed for food without stepping off the trail. But before long not a buffalo could be found within shooting distance of the Platte. When the Union Pacific was built along this river, the buffalo were divided forever -- with the greatest numbers living south of the Platte in the Southern Herd.

Despite the separation, the animals were plentiful. Steamboats on the upper Missouri would stop and wait when a herd wanted to cross the river. In the frontier cowtown of

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Wichita, choice buffalo humps sold for three cents a pound. In May of 1871 Col. Richard I. Dodge traveled along the Arkansas River in central Kansas from old Fort Zarah to Fort Larned, a distance of 35 miles, through a huge herd moving northward.

"At least 25 miles of that distance," he later recalled, "was through one immense herd," adding that it took this bunch 5 days to pass a given point.

At approximately the same time that Colonel Dodge picked his way through a herd later estimated to contain 4 million buffalo, industrialists in the East suddenly discovered that buffalo leather, for many purposes, was unexcelled. One firm ordered several thousand hides, and almost overnight a strange breed of men, the professional hide hunter, was born. Armed with recently perfected long-range breechloading rifles, hide hunters could sneak to within 200 or 300 yards of a herd and pump lead into it as long as the herd was within range. Not since gold fever had gripped the restless in '49 had so many Americans flocked to one section of the country. The railroads brought hunters in by the trainload, carrying buffalo hides on the return trip.

On September 23, 1872, tracks of the Santa Fe Railway reached the Kansas hamlet of Dodge City, which soon became the headquarters from which the extermination of the Southern Herd was to be directed. By December there were at least 2,000 hide hunters employed in the buffalo-killing industry. The hide of a full-grown bull -- which would stand six feet at the shoulders and weigh 1,800 pounds -- brought 75 cents to $2.50, depending on its condition. Good winter robes commanded from $4 to $6. Salted tongues, about the only meat saved, earned hunters a quarter and sold for 50¢ in the East. By January 1, 1873, the Santa Fe had hauled 43,000 hides from Dodge. A few persons started to wonder if Satanta had been right when he predicted the whites would kill off the buffalo.

"Each hide counts a buffalo slain," the editor of one frontier newspaper wrote when he learned how many hides were shipped from Dodge, "and 43,000 hides in three months convey an idea of magnificent butchery that forecasts the speedy extinction of the prairie denizen."

The editor's arithmetic appears logical, but it wasn't. The 43,000 hides probably represented at least 150,000 dead buffalo, maybe more. Experts like Colonel Dodge estimated that for every hide that reached the market, from two to five animals were killed, because most of the hide men were not frontiersmen and they ruined many of the hides during the skinning process.

The "magnificent butchery" continued unabated. As buffalo became harder to find, better organization was necessary. The normal hunting party was made up of the hunter, four skinners and a cook. Buffalo usually were shot in the morning after they had been to water and were lying down to rest. The hunter, using two guns and a forked stick or tripod as a support, often killed 50 animals without moving from his track; 200 a day was a normal kill -- for a skinner could rip the hides from about 25 buffalo in a day.

William Blackmore, a London sportsman who traveled for 40 miles along the Arkansas River in the Fall of 1873, reported: "There was a continual line of putrescent carcasses, so that the air was rendered pestilential and offensive to the last degree. The hunters had formed a line of camps along the banks of the river and had shot down the buffalo, night and morning, as they came to drink. In order to give an idea of these carcasses, it is necessary

to mention that I counted 67 on one spot not covering four acres."

This slaughter was repeated on the Platte, the Smoky, the Pawnee, the Republican, the Solomon, the Walnut and the Saline Rivers, and their tributaries.

"Every drink of water, every mouthful of grass," said a Cavalry officer who witnessed the orgy, "is at the expense of life, and the miserable animals, continually harassed, are driven into localities far from their natural haunts, anywhere to avoid the increasing pursuits."

Voices crying out against the slaughter became more voluble. In 1874 a bill was introduced in the Texas Legislature to protect buffalo. However, General Phil Sheridan, the Civil War hero, appeared before the lawmakers and pointed out that buffalo were the commissary of the Indians, insisted that the extermination was necessary to our colonial expansion.

"One party of 16 hunters killed 28,000 buffalo last summer," the United States Congress was told. That was an average of 1,750 buffalo per hunter, slain at a season when meat was impossible to save and worthless as food.

But it was too late for tears. Nothing could save the vast herds of buffalo. The Kansas Pacific, Union Pacific and Santa Fe during a 3-year period (1872-74) shipped to the East 1.3 million hides, 6.7 million pounds of meat and 32 million pounds of buffalo bones -- used mostly for fertilizer. Considering the wasted animals, probably 4.3 million buffalo -- the bulk of the Southern Herd -- were killed in these 3 years. Congress talked of interfering, but didn't. The buffalo melted like snow beneath a hot summer's sun. At the close of the hunting season of 1875, the remnant of the great Southern Herd fled south toward the *Llano Estacado*.

The Dodge City-based hunters headed south also, despite the fact that the Medicine Lodge treaty forbade them to do so. More hunters made their headquarters at Fort Worth, Texas. From 1876 to 1878 there were 300,000 additional skins marketed by 1,500 hunters, who for all practical purposes wiped out the Southern Herd.

The Northern Herd -- which numbered a about 1.5 million -- survived a few more years on the high plains of the Dakotas, Montana and Wyoming. In 1880, summer hunt began in the north, and the herd had all but vanished by the end of the 1882-3 season. And in another 3 years Indians in Canada were starving because most of the buffalo there were gone.

A few wary buffalo continued to exist here and there. In 1887 a Texas rancher discovered a herd of about 200 in the Panhandle between the two forks of the Canadian River. His party killed 75. By this time the buffalo were so rare that the heads brought $50 apiece, the robes $200.

Teddy Roosevelt, hunting in the fall of 1889 in Idaho, was deeply moved when he trained his sights on what certainly must have been among the last of the survivors.

"Mixed with the eager excitement of the hunter," noted Roosevelt, "was a half-melancholy feeling as I gazed on these bison, themselves part of the last remnant of a doomed and nearly vanished race."

And vanish they nearly did. By 1890 there were fewer than 1,000 buffalo in the United States. At this point a few individuals and the federal government began giving long-withheld protection. Happily the buffalo never vanished, and there probably are 20,000 in scattered

Canadian and American herds today. Naturalists estimate there must have been 70 million buffalo in the 1700's. By 1800 there were no buffalo east of the Mississippi, but 40 million in the 3 million square miles of open plains. It wasn't until the buffalo were nearly gone that these attempts to count them were made. The revelations were appalling, but to the end the hide hunters showed no pity for the buffalo.

"Pity?" a puzzled veteran hide hunter said in 1930 a half century after the big kill. "No, I did not feel it. It was business with me. I had money invested .... if I did not butcher the buffaloes, there were many other hunting outfits around me that would, so I killed all I could.

"I and the thousands of other buffalo hunters had no high-minded motives in slaughtering the buffalo. We were after his hide and the money it would bring, but yet the buffalo hunter was the true pioneer who cleared the way for the cowboy and steer, the settler with his plow, the church and school and civilization ... When we killed off the buffalo, the Indian's commissary was gone, he was starved into submission, went upon his reservation. The country never could have been settled so long as the buffalo was here to support the Indian."

II. HOW *BUFLO* SIMULATES THE NATURAL LIFE CYCLE OF THE AMERICAN BISON

The buffalo's life cycle starts with the birth of the new calves. Birth takes place after the melting of the winter's snows in April or May, depending on the location. The *BUFLO* program reports the population immediately following calving. Because of this, the population may occasionally rise above the carrying capacity, the greatest number of buffalo which the range can support. This surplus population will usually be eliminated through predation and natural mortality.

Soon after birth, the new calves are able to travel with the rest of the herd and for the rest of their first year they will be dependent on their mother for protection and nutrition. Should the mother be killed, the calf will die as well. *BUFLO* takes this effect into account. If female adults are harvested (killed by hunters), a corresponding drop in the number of calves surviving to become yearlings will be noticed in a report the following spring.

Hunting parties seldom started until calving was finished because snows limited the hunter's access to the herds. But once started, hunting continued into the late fall, until weather made conditions unbearable (and unprofitable) for the hunter. Thus, the harvest was spread over the entire summer and fall. *BUFLO* takes this hunting distribution into consideration in simulating mating activity. This is necessary since mating usually takes place in August, about halfway through the hunting season. For the purposes of establishing fertility, *BUFLO* assumes that one half of the harvest takes place before mating.

During the August mating, males join the female herds and mating activities start as females come into heat. The most dominant male usually mates with the first female to come into heat, the second male with the second female and so on. However, the males are polygamous. As soon as the mating activity of a pair is over, the male will attempt to mate with any other female coming into heat. In this way, a single dominant male buffalo may mate with several females in a single year. *BUFLO* assumes that a male buffalo may mate with a maximum of 10 females during a single mating season. If the number of male buffalo comes to be less than 10% of the female population, *BUFLO* assumes that several of the females will not become pregnant, and will not produce calves the following spring. This effect can be seen by hunting out all the adult males.

A female buffalo can mate during her third year and produce a single offspring each year for thirty years. Observations of buffalo herds have established that mating patterns nearly guarantee the pregnancy of every fertile female. *BUFLO* assumes that if males are available, every female will become pregnant (see above); but that only a certain number of these preguancies will be successful in producing live offsrping.

Mortality from natural causes reaches its peak during the winter months. During this time heavy snows may cover the grasses needed by the buffalo, and travel becomes much more difficult. Large kills have been recorded when the buffalo herd had attempted to cross half-frozen rivers. Animals in the back of the herd pushed those in front through the broken ice.

BUFLO assumes that the winter mortality rate is independent of hunting that has taken place during the previous summer. *BUFLO* also assumes that the winter herd population has an effect on the birth rate the following spring. If the population of the herd entering the winter is very near the carrying capacity, then conditions will be very hard on the individual buffalo and this will result in fewer live births the following spring. This effect can be seen by doing no hunting, and viewing the graph of the calves as the population nears the carrying capacity.

With the coming of spring, the calves are now yearlings and the previous year's yearlings become adults. With the birth of the new calves, the buffalo life cycle starts once again.

III. ANNOTATED SAMPLE RUNS

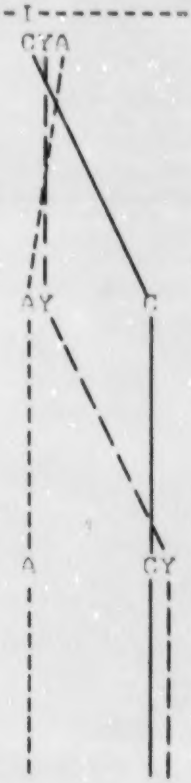
RUN #1 In this run the student starts with a population of 400 buffalo and lets them reproduce until there are 800 in the herd. At that point the student attempts to halt further growth of the population through selective harvest.

```
HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO) ?0

CONSULT THE STUDENT MANUAL FOR INFORMATION ON
INITIALIZATION OF THE MODEL.

BUFLO USES THE FOLLOWING CODE:
      AM=ADULT MALES          AF=ADULT FEMALES
      YM=YEARLING MALES       YF=YEARLING FEMALES
      CM=CALF MALES           CF=CALF FEMALES

THERE ARE TWO POLICIES OF HERD MANAGEMENT AVAILABLE.
TOTAL FREEDOM OF HERD CONTROL (1)
OR AUTOMATIC SAFEGUARDS FOR HERD POPULATION (2)
WHICH POLICY DO YOU PREFER ?1

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?20,2,1

CARRYING CAPACITY ?4000

STARTING YEAR= ?1974

WILL YOU INITIALIZE NUMBER OF BUFFALO BY
BREAKDOWN (1) OR TOTAL HERD (2) ?2
TOTAL BUFFALO IN HERD ?400
```

STUDENT WILL CARRY OUT A TWENTY YEAR STUDY, CHANGE HARVESTING EVERY SECOND YEAR AND GET A POPULATION REPORT EVERY YEAR.

```
                        HARVEST
SYM/GROUP   POP          QUOTA
---------   ---          -----
SPRING OF YEAR  1974
HERD SIZE= 400
A   AM   151              ?0
A   AF   135              ?0
Y   YM    24              ?0
Y   YF    18              ?0
C   CM    36              ?0
C   CF    36              ?0

SPRING OF YEAR  1975
HERD SIZE= 446
A   AM   152
A   AF   134
Y   YM    22
Y   YF    22
C   CM    60
C   CF    56

SPRING OF YEAR  1976
HERD SIZE= 472
A   AM   152              ?0
A   AF   136              ?0
Y   YM    36              ?0
Y   YF    34              ?0
C   CM    59              ?0
C   CF    55              ?0
```

NO HARVEST OF ANY GROUP



STUDENT HAS CONNECTED POINTS ON THE NORMALIZED GRAPH
A=ADULTS Y=YEARLINGS
C=CALVES

```
SPRING OF YEAR  1977
HERD SIZE= 491
A  AM  162
A  AF  146
Y  YM  35
Y  YF  33
C  CM  60
C  CF  55

SPRING OF YEAR  1978
HERD SIZE= 518
A  AM  171              ??
A  AF  155              ??
Y  YM  36               ??
Y  YF  33               ??
C  CM  64               ??
C  CF  59               ??

SPRING OF YEAR  1979
HERD SIZE= 546
A  AM  179
A  AF  163
Y  YM  38
Y  YF  35
C  CM  68
C  CF  63

SPRING OF YEAR  1980
HERD SIZE= 575
A  AM  188              ??
A  AF  171              ??
Y  YM  41               ??
Y  YF  38               ??
C  CM  71               ??
C  CF  66               ??

SPRING OF YEAR  1981
HERD SIZE= 606
A  AM  198
A  AF  181
Y  YM  43
Y  YF  40
C  CM  75
C  CF  69

SPRING OF YEAR  1982
HERD SIZE= 638
A  AM  209              ??
A  AF  191              ??
Y  YM  45               ??
Y  YF  41               ??
C  CM  79               ??
C  CF  73               ??

SPRING OF YEAR  1983
HERD SIZE= 671
A  AM  220
A  AF  201
Y  YM  47
Y  YF  44
C  CM  83
C  CF  76
```

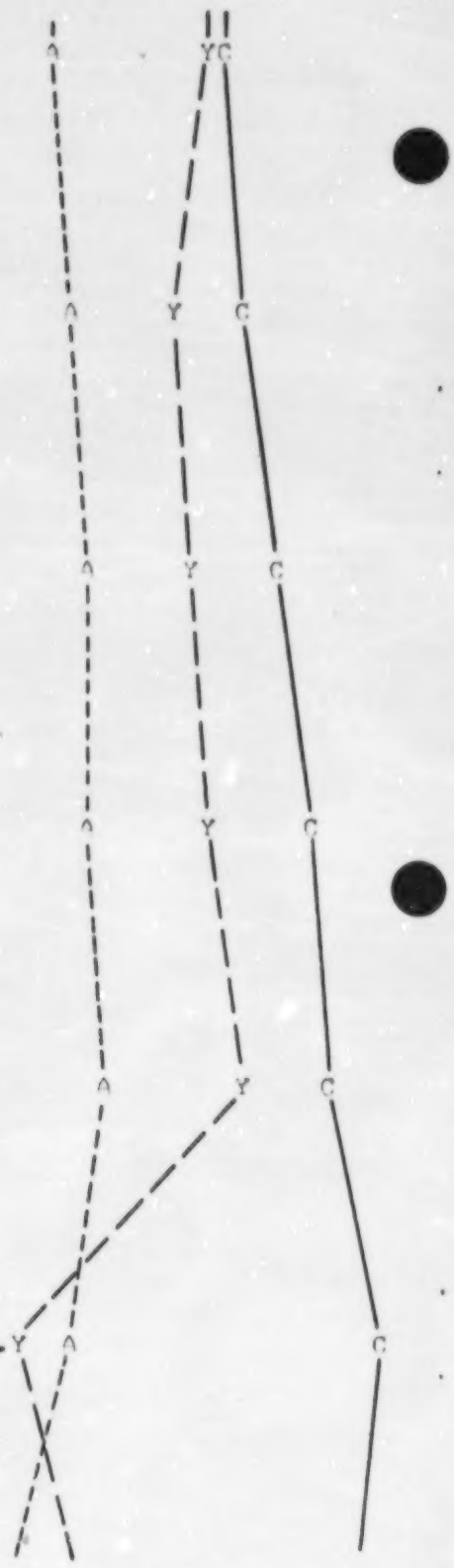
STUDENT CONTINUES TO DO NO HARVESTING. POPULATION GROWS. NOTE THAT POINTS ON GRAPH GO TO THE RIGHT.

```
SPRING OF YEAR  1984
HERD SIZE= 707
A   AM   232          ?0
A   AF   212          ?0
Y   YM    50          ?0
Y   YF    46          ?0
C   CM    87          ?20
C   CF    80          ?0

SPRING OF YEAR  1985
HERD SIZE= 732
A   AM   245
A   AF   224
Y   YM    40
Y   YF    48
C   CM    91
C   CF    84

SPRING OF YEAR  1986
HERD SIZE= 762
A   AM   240          ?0
A   AF   236          ?0
Y   YM    43          ?0
Y   YF    50          ?0
C   CM    96          ?25
C   CF    88          ?0

SPRING OF YEAR  1987
HERD SIZE= 793
A   AM   255
A   AF   248
Y   YM    43
Y   YF    53
C   CM   101
C   CF    93

SPRING OF YEAR  1988
HERD SIZE= 825
A   AM   263          ?50
A   AF   261          ?0
Y   YM    46          ?10
Y   YF    56          ?30
C   CM   105          ?50
C   CF    97          ?50

SPRING OF YEAR  1989
HERD SIZE= 746
A   AM   215
A   AF   253
Y   YM    33
Y   YF    38
C   CM   113
C   CF   104
```

STUDENT HAS ELECTED TO HARVEST 20 MALE CALVES PER YEAR.

1984 HARVESTING POLICY IS STILL IN EFFECT BECAUSE THE POLICY CHANGE INTERVAL WAS SET FOR TWO YEARS.

RELATIVELY LARGE CALF HARVEST LOWERS YEARLING POPULATION IN SUCCEEDING YEARS AS SHOWN ON GRAPH



SPRING OF YEAR 1990
HERD SIZE= 673

A	AM	164	??
A	AF	226	??
Y	YM	38	??
Y	YF	32	??
C	CM	111	??
C	CF	102	??

DRASTIC HARVESTS OF 1988 AND 1989 FORCED POPULATION TO FALL BELOW 800 OBJECTIVE.

SPRING OF YEAR 1991
HERD SIZE= 716

A	AM	175
A	AF	226
Y	YM	67
Y	YF	61
C	CM	97
C	CF	90

SPRING OF YEAR 1992
HERD SIZE= 752

A	AM	226	??
A	AF	248	??
Y	YM	58	??
Y	YF	54	??
C	CM	97	?1?
C	CF	89	??

SPRING OF YEAR 1993
HERD SIZE= 798

A	AM	267
A	AF	262
Y	YM	52
Y	YF	53
C	CM	106
C	CF	98

SPRING OF YEAR 1994
HERD SIZE= 846

A	AM	242
A	AF	274
Y	YM	58
Y	YF	59
C	CM	111
C	CF	102

TOTAL HARVEST IN 20 YEARS IS 483 BUFFALO.

RUN #2 — Here the student has selected *AUTOMATIC SAFEGUARDS* to protect the buffalo population. He is studying the effect of harvesting all of the yearlings.

```
                    BUFFALO HERD MANAGEMENT

HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO) ?1

WHICH POLICY DO YOU PREFER ?2

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?30,5,5

CARRYING CAPACITY ?40E6

STARTING YEAR= ?1900

WILL YOU INITIALIZE NUMBER OF BUFFALO BY
BREAKDOWN (1) OR TOTAL HERD (2) ?2
TOTAL BUFFALO IN HERD ?20E6
```

CHOICE TWO WILL STOP HARVESTING IF EITHER THE ADULTS FALL BELOW A CERTAIN LEVEL OR IF THE ADULT QUOTAS EXCEED A DANGER LEVEL. THUS THE HERD IS PROTECTED AGAINST EXCESSIVE HARVESTING.

SYM/GROUP	POP	HARVEST QUOTA
SPRING OF YEAR 1900		
HERD SIZE= 20000000		
A AM	7560000	?0
A AF	6760000	?0
Y YM	1040000	?1040000
Y YF	920000	?920000
C CM	1800000	?0
C CF	1720000	?0
SPRING OF YEAR 1905		
HERD SIZE= 15656577		
A AM	4727484	?0
A AF	4746038	?0
Y YM	1934931	?1934931
Y YF	1139936	?1139936
C CM	1388958	?0
C CF	1897930	?0
SPRING OF YEAR 1910		
HERD SIZE= 9772767		
A AM	2791526	?0
A AF	2832482	?0
Y YM	862937	?862937
Y YF	796529	?796529
C CM	1310048	?0
C CF	1939275	?0

```
SPRING OF YEAR  1915                A  CY
HERD SIZE= 5856936
A   AM   1648362          ?0
A   AF   1654831          ?0
Y   YM   535153           ?535153
Y   YF   493987           ?493987
C   CM   808378           ?0
C   CF   746135           ?0

SPRING OF YEAR  1920                A CY
HERD SIZE= 3517738
A   AM   973335           ?0
A   AF   977156           ?0
Y   YM   325178           ?325178
Y   YF   300164           ?300164
C   CM   489775           ?0
C   CF   452130           ?0

HERD PUT IN DANGER OF EXTINCTION DURING YEAR  1920
NO MORE HARVESTING UNTIL HERD IS SAFE.
IN ORDER TO LOWER CHANCE OF EXTINCTION,
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0

HERD OUT OF DANGER IN YEAR  1924
HARVESTING NOW PERMITTED
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0

HERD PUT IN DANGER OF EXTINCTION DURING YEAR  1924
NO MORE HARVESTING UNTIL HERD IS SAFE.
IN ORDER TO LOWER CHANCE OF EXTINCTION,
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0

SPRING OF YEAR  1925                AYC
HERD SIZE= 2543445
A   AM   736541
A   AF   726350
Y   YM   193730
Y   YF   173898
C   CM   368158
C   CF   332938

HERD OUT OF DANGER IN YEAR  1926
HARVESTING NOW PERMITTED
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?1

SPRING OF YEAR  1926                ACY
HERD SIZE= 2654510
A   AM   833183           ?0
A   AF   787835           ?0
Y   YM   228895           ?228895
Y   YF   203203           ?203203
C   CM   382521           ?0
C   CF   364173           ?0

HERD PUT IN DANGER OF EXTINCTION DURING YEAR  1926
NO MORE HARVESTING UNTIL HERD IS SAFE.
IN ORDER TO LOWER CHANCE OF EXTINCTION,
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0
```

AFTER THIS MESSAGE IS TYPED, NO HARVESTING TAKES PLACE UNTIL THE HERD IS DECLARED OUT OF DANGER.

EVEN THOUGH THE HERD HAS BEEN DECLARED TO BE IN DANGER AND HARVESTING HAS BEEN HALTED, QUOTAS ARE STILL ASKED FOR. HOWEVER, THESE QUOTAS WILL NOT BE IMPLEMENTED UNTIL THE HERD IS OUT OF DANGER.

```
HERD OUT OF DANGER IN YEAR  1928
HARVESTING NOW PERMITTED
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0

HERD PUT IN DANGER OF EXTINCTION DURING YEAR  1928
NO MORE HARVESTING UNTIL HERD IS SAFE.
IN ORDER TO LOWER CHANCE OF EXTINCTION,
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0

HERD OUT OF DANGER IN YEAR  1930
HARVESTING NOW PERMITTED

SPRING OF YEAR  1931                ACY
HERD SIZE= 2573814
A   AM   735161
A   AF   761432
Y   YM   212248
Y   YF   195221
C   CM   316797
C   CF   392345


 TOTAL HARVEST IN 30 YEARS IS 35452896 BUFFALO.
```

PREVIOUSLY ESTABLISHED QUOTAS ARE THEN IMPLEMENTED.

RUN #3 { Student has selected *TOTAL FREEDOM OF HERD CONTROL* and has driven the buffalo to extinction.

```
                    BUFFALO HERD MANAGEMENT

HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO) ?1

WHICH POLICY DO YOU PREFER ?1

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?15,0,1

CARRYING CAPACITY ?10000

STARTING YEAR= ?1950

WILL YOU INITIALIZE NUMBER OF BUFFALO BY
BREAKDOWN (1) OR TOTAL HERD (2) ?2
TOTAL BUFFALO IN HERD ?3000

                          HARVEST          PERCENTAGE OF ORIGINAL POPULATION
SYM/GROUP  POP            QUOTA       0              100             200             300
---------  ---            -----       I--------------I--------------I--------------I
SPRING OF YEAR  1950                                  CYA
HERD SIZE= 3000
A  AM  1134               ?934
A  AF  1014               ?814
Y  YM  186                ?186
Y  YF  138                ?138
C  CM  273                ?273
C  CF  255                ?255

HERD PUT IN DANGER OF EXTINCTION DURING YEAR  1950
WE WILL CONTINUE AS YOU WISH.

SPRING OF YEAR  1951                  Y A C
HERD SIZE= 535
A  AM  179
A  AF  179
Y  YM  0
Y  YF  0
C  CM  99
C  CF  85

YOU HAVE SUCCEEDED IN COMPLETELY DESTROYING
THE BUFFALO HERD BY  1951

 TOTAL HARVEST IN 2 YEARS IS 3135 BUFFALO.

DO YOU WANT ANOTHER RUN (1=YES, 0=NO) ?0
```

IF TOTAL FREEDOM IS SELECTED, THIS MESSAGE SERVES ONLY AS A WARNING. HARVESTING CONTINUES.

IV. *BUFLO* PROGRAM LISTING

```
100 REM BUFLO -- PROGRAM SIMULATING THE RESOURCE MANAGEMENT OF
105 REM BUFFALO HERDS -- **THREE VARIABLE GRAPH VERSION
110 REM COPYRIGHT 1973, STATE UNIVERSITY OF NEW YORK
115 REM MODEL DEVELOPED BY L.BRAUN, J. FRIEDLAND
120 REM PROGRAMMED BY L. BRAUN, REVISED BY M. WEISNER AND B. ESRIG
125 REM LATEST REVISION: 11-28-73
130 DIMS(3),P(6),M(6),O(6),H(6),Z(2)
135 DEFFNA(X)=SGN(SGN(X)+1)
140 DEFFNB(I)=INT(I)*FNA(INT(I))
145 PRINT"","BUFFALO HERD MANAGEMENT"
150 PRINT
155 PRINT"HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO)";
160 INPUTD
165 PRINT
170 IFD=1THEN230
175 PRINT"CONSULT THE STUDENT MANUAL FOR INFORMATION ON"
180 PRINT"INITIALIZATION OF THE MODEL."
185 PRINT
190 PRINT"BUFLO USES THE FOLLOWING CODE:"
195 PRINT"      AM=ADULT MALES","AF=ADULT FEMALES"
200 PRINT"      YM=YEARLING MALES","YF=YEARLING FEMALES"
205 PRINT"      CM=CALF MALES","CF=CALF FEMALES"
210 PRINT
215 PRINT"THERE ARE TWO POLICIES OF HERD MANAGEMENT AVAILABLE."
220 PRINT"TOTAL FREEDOM OF HERD CONTROL (1)"
225 PRINT"OR AUTOMATIC SAFEGUARDS FOR HERD POPULATION (2)"
230 PRINT"WHICH POLICY DO YOU PREFER";
235 INPUTD
240 IF(D-1)*(D-2)<>0THEN230
245 PRINT
250 PRINT"YEARS FOR OBSERVE, CHANGE POLICY, REPORT";
255 INPUTZ0,P0,R0
260 IFP0*R0=0THEN175
265 PRINT
270 PRINT"CARRYING CAPACITY";
275 INPUTE
280 IFE<>INT(ABS(E))THEN270
285 IFE<=6E7THEN300
290 PRINT"CARRYING CAPACITY MUST BE LESS THAN 60 MILLION."
295 GOTO270
300 PRINT
305 LETH=0
310 LETF5=0
315 LETF1=0
320 PRINT"STARTING YEAR=";
325 INPUTT0
330 IFT0<>INT(ABS(T0))THEN320
335 LETT=T0
340 PRINT
345 RESTORE
350 PRINT"WILL YOU INITIALIZE NUMBER OF BUFFALO BY"
355 PRINT"BREAKDOWN (1) OR TOTAL HERD (2)";
360 INPUTG1
365 IFG1=1THEN390
370 IFG1<>2THEN350
```

```
375 PRINT"TOTAL BUFFALO IN HERD";
380 INPUTT5
385 IFT5<>INT(ABS(T5))THEN375
390 FORI=1TO6
395 READZ(I)
400 LETP(I)=INT(Z(I)*T5)
405 IFG1=2THEN435
410 PRINT"HOW MANY";
415 GOSUB900
420 PRINT" BUFFALO";
425 INPUTP(I)
430 IFP(I)<>INT(ABS(P(I)))THEN415
435 NEXTI
440 IFG1=1THEN450
445 LETP(6)=T5-P(1)-P(2)-P(3)-P(4)-P(5)
450 FORI=1TO6
455 READM(I)
460 LETH(I)=P(I)
465 NEXTI
470 PRINT
475 PRINTTAB(19);"HARVEST";
480 PRINTTAB(34);"PERCENTAGE OF ORIGINAL POPULATION"
485 PRINT"SYM/GROUP";TAB(11);"POP";(20);"QUOTA";
490 PRINTTAB(30);"0";TAB(42);"100";TAB(55);"200";TAB(68);"300"
495 PRINT"---------";TAB(11);"---";TAB(20);"-----";
500 PRINTTAB(30);"I-----------I-----------I-----------I"
505 READZ(1),Z(2)
510 PRINT"SPRING OF YEAR ";T;
515 GOSUB935
520 PRINT"HERD SIZE=";
525 PRINTP(1)+P(2)+P(3)+P(4)+P(5)+P(6)
530 FORI=1TO6
535 GOSUB1055
540 GOSUB900
545 PRINTTAB(6);P(I);
550 IFF1=1THEN565
555 IFINT((T-T0)/P0)<>(T-T0)/P0THEN585
560 IFD+F5=3THEN585
565 PRINTTAB(20);
570 INPUTQ(I)
575 IFABS(INT(Q(I)))<>Q(I)THEN535
580 GOTO590
585 PRINT
590 NEXTI
595 PRINT
600 IFT-T0=Z0THEN1105
605 LETQ7=Q(1)*ABS(SGN(F5+D-3))
610 LETQ8=Q(2)*ABS(SGN(F5+D-3))
615 LETF0=(1-Q8/(P(2)+.1))*FNA(1-Q8/(P(2)+.1))
620 LETM9=(P(1)-Q7/2)*FNA(P(1)-Q7/2)
625 LETF9=(P(2)-Q8/2)*FNA(P(2)-Q8/2)
630 LETP9=(P(2)-Q8)*(1-M(2))*SGN(M9*F9)
635 IFF9/10<M9THEN645
640 LETP9=10*M9*(1-M(2))*SGN(M9*F9)*(1-Q8/2/(F9+.01))
645 IFD+F5=3THEN685
650 FOR I=1 TO 6
655 LETH=H+Q(I)
660 LETP(I)=P(I)-Q(I)
```

```
665 IFP(I)>=0 THEN 680
670 LETH=H+P(I)
675 LETP(I)=0
680 NEXTI
685 LETP7=P(1)+P(2)+P(3)+P(4)+P(4)+P(5)+P(6)
690 IFP7=0THEN1000
695 FORI=1TO2
700 LET P(I)=FNR((1-M(I))*P(I)+(1-M(I+2))*P(I+2)-1)
705 LET P(I+2)=FNR((1-M(I+4))*P(I+4)*F0+.5)
710 LET P(I+4)=FNR(Z(I)*P0*(1-.45*P7/E)+.5)
715 NEXTI
720 LETF1=0
725 IFP(1)<.019*ETHEN800
730 IFP(1)<Q(1)/2THEN800
735 IFP(2)<Q(2)/2THEN800
740 IFP(2)<.017*ETHEN800
745 IFF5=0THEN855
750 PRINT"HERD OUT OF DANGER IN YEAR ";T+1
755 LETF5=0
760 IFD=1THEN850
765 PRINT"HARVESTING NOW PERMITTED"
770 IFINT((T+1-T0)/P0)=(T+1-T0)/P0THEN850
775 REM SKIP IF POLICY YEAR
780 PRINT"DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO)";
785 INPUTF1
790 IFF1*(F1-1)<>0THEN780
795 GOTO850
800 IFF5=1THEN855
805 REM DANGER OF EXTINCTION
810 PRINT"HERD PUT IN DANGER OF EXTINCTION DURING YEAR ";T
815 LETF5=1
820 IFD=1THEN845
825 PRINT"NO MORE HARVESTING UNTIL HERD IS SAFE."
830 IFP(1)+P(2)=0THEN780
835 PRINT"IN ORDER TO LOWER CHANCE OF EXTINCTION,"
840 GOTO780
845 PRINT"WE WILL CONTINUE AS YOU WISH."
850 PRINT
855 LETT=T+1
860 IFT-T0<>Z0THEN880
865 LETF1=0
870 LETP0=2E7
875 GOTO510
880 IFINT((T-T0)/P0)=(T-T0)/P0THEN510
885 IFINT((T-T0)/R0)=(T-T0)/R0THEN510
890 IFF1=1THEN510
895 GOTO600
900 PRINT"  ";
905 GOSUB1055
910 IF I/2=INT(I/2)THEN925
915 PRINT"M";
920 GOTO930
925 PRINT"F";
930 RETURN
935 FORI=2TO6STEP2
940 IFH(I)+H(I-1)<>0 THEN 955
945 LETS(I/2)=43
```

57

```
950 GOTO960
955 LETS(I/2)=(P(I)+P(I-1))*13/(H(I)+H(I-1))+30
960 NEXTI
965 LETI1=1
970 FORJ=1TO3
975 FORI=1TO3
980 IFS(I)>S(I1)THEN990
985 LETI1=I
990 NEXTI
995 LETI=2*I1
1000 IFS(I1)>70THEN1035
1005 PRINTTAB(S(I1));
1010 GOSUB1055
1015 LETS(I1)=4E8
1020 NEXTJ
1025 PRINT
1030 RETURN
1035 PRINTTAB(68);
1040 GOSUB1055
1045 PRINT"->";
1050 GOTO1015
1055 IF I>2 THEN 1065
1060 PRINT"A";
1065 IF ABS(I-3.5)>.5 THEN 1075
1070 PRINT"Y";
1075 IF I<5 THEN 1085
1080 PRINT"C";
1085 RETURN
1090 PRINT"YOU HAVE SUCCEEDED IN COMPLETELY DESTROYING"
1095 PRINT"THE BUFFALO HERD BY ";T
1100 LETT=T+1
1105 PRINT
1110 PRINT" TOTAL HARVEST IN";T-T0;"YEARS IS";H;"BUFFALO."
1115 DATA.378,.338,.062,.046,.091
1120 DATA 0
1125 DATA.1,.1
1130 DATA.25,.25
1135 DATA.4,.4
1140 DATA.52,.48
1145 PRINT
1150 PRINT"DO YOU WANT ANOTHER RUN (1=YES, 0=NO)";
1155 INPUTD
1160 IFD=1THEN230
1165 END
```

V. LIST OF VARIABLES

Variable	Meaning
D	Policy decision flag
E	Environmental carrying capacity
FØ	Proportion of the adult females harvested
F1	Off-year policy set flag
F5	Harvesting - Herd Condition flag
F9	Number of adult females present at time of mating
GØ	Instruction flag
G1	Temporary response and number holder
H	Total harvest
H(1)-H(6)	Initial population of each cohort
I	Index
II	Index
J	Index
M9	Number of adult males present at time of mating
M(1)-M(6)	Mortality (% deaths/year) of each age-sex group
PØ	Policy adjustment interval
P9	Number of pregnant adult females
Q7	Effective adult male harvest
Q8	Effective adult female harvest
Q(1)-Q(6)	Harvest quota/year for each age-sex group
RØ	Report interval
S(1)-S(3)	Graph TAB location

Variable	Meaning
T	Year number
TØ	Initial Year
T5	Total number of buffalo in initial herd
ZØ	Time interval
Z1	Proportion of calves born male
Z2	Proportion of calves born female

When Subscript Equals	Variable Refers To
1	Adult Males
2	Adult Females
3	Yearling Males
4	Yearling Females
5	Calf Males
6	Calf Females

VI. FORMULAS

A. Population Structure

$$P_7 = P_1 + P_2 + P_3 + P_4 + P_5 + P_6$$

Where P_7 equals the total population and P_1 through P_6 represent Adult Males, Adult Females, Yearling Males, Yearling Females, Calf Males and Calf Females respectively.

B. Fertility and Birth

1) Number of pregnancies carried through to spring

If Adult Females are at least ten times as numerous as Adult Males:

$$P_9 = (P_2 - Q_8) * (1 - M_2)$$

Where P_9 equals pregnancies, Q_8 represents effective female Harvest and M_2 equals mortality in Adult Females.

If Adult Females are more numerous than ten times the number of Adult Males, then:

$$P_9 = 10 * M_9 * (1 - M_2) * \left(1 - \frac{Q_8/2}{F_9}\right)$$

Where M_9 and F_9 equal the number of Adult Males and Females present at the time of mating.

2) Births

$$P_5 = Z_1 * P_9 * [1 - (.45 * P_7/E)]$$

$$P_6 = Z_2 * P_9 * [1 - (.45 * P_7/E)]$$

Where E equals the environmental carrying capacity, Z_1 and Z_2 equal the proportion of male and female births, respectively.

C. Aging and Mortality

$$P_1 = [P_1^1 * (1 - M_1) + P_3^1 * (1 - M_3) - 1]$$

$$P_2 = [P_2^1 * (1 - M_2) + P_4^1 * (1 - M_4) - 1]$$

Where primed variables represent old values and unprimed variables represent the resultant values.

$$P_3 = [P_5 * (1 - M_5) * F_\emptyset]$$

$$P_4 = [P_6 * (1 - M_6) * F_\emptyset]$$

Where $F_\emptyset$ equals the proportion Adult Females harvested during the preceding year.

D. Harvest

$$H = H^1 + Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6$$

If any quota ($Q_1 - Q_6$) exceeds the available population, then

$$Q_1 = P_1$$

Therefore, the populaiion is lowered by its specific age-sex group quota or its propulation, if quota exceeds the available population

$$P_1 = P_1^1 - Q_1$$

VII. *BUFLO* MODEL ASSUMPTIONS

1) Nonhunting mortality is independent of hunting quota. For any single year, 10% of the adults, 25% of the yearlings and 40% of the calves will die. All mortality is assumed to take place after the hunting season.

   Increased mortality occurs in calves as adult females are harvested. This is based on the assumption that calves are dependent on their mothers during the entire first year.

2) All harvesting takes place during late spring, summer and early autumn. Approximately one half of the quota has been harvested by mating season.

3) As total population approaches the carrying capacity, the birth rate falls to 55% of its maximum value. It is assumed that all individuals have an equal environmental impact.

4) It is assumed that each adult male bull can successfully mate with up to 10 adult females.

5) If the quota exceeds the population of a particular sex-age group, the entire sex-age group will be harvested. One half of the original quota will be harvested before mating season.

6) The herd is defined as "in danger of extinction" if the population of adult males or adult females falls below one twentieth of the normal population at the carrying capacity.

7) No harvest is taken the last year of the program. A report is given for the spring of the year and then the program is terminated. (If the student wishes to continue this run, he may initialize another run from the last report, with the same results as if the run had been continued.)

8) There is no immigration or emigration of buffalo from the area being studied.

9) It is assumed that the buffalo assemble in a single interacting herd, especially as the numbers become small.

10) No female may become pregnant until the third year. A gestation period of nine and one half months places the first possible birth in the female's fourth year. After the fourth year, a cow may produce one birth per year.

11) Males are assumed to play no role in raising or protecting the young.

12) There is no fixed maximum lifespan for the buffalo, but most buffalo are assumed to die before old age (approximately 30 years).

13) If the buffalo herd is initialized by "TOTAL HERD" (Choice 2), the cohorts are set:

37.8%	Adult male
33.8%	Adult female
6.2%	Yearling male
4.6%	Yearling female
9.1%	Calf male
8.5%	Calf female

14) 52% of all live births are male and 48% of all live births are female.

VIII. FURTHER STUDENT INVESTIGATIONS

1) Effect of Changing Calf Mortality

Mortality of calves is always highest in the winter months, but this mortality may vary greatly with the severity of the weather. The effects of higher or lower calf mortality may be simulated by altering two values stored in line 1135 of the *BUFLO* program. Currently line 1135 reads 1135 DATA.4,.4 which represents a calf mortality equal to 40%. The first number represents mortality in male calves and the second is for female calves. These numbers may be replaced with any number from Ø to 1, where Ø represents no mortality, and 1 represents complete mortality.

For example, if you wish to set both male and female mortality to 60%, you would type:

1135 DATA.6Ø,.6Ø

before you type RUN".

2) The Effect of Differing Sex Ration in Births

BUFLO assumes that 52% of the live births will be male and 48% female. This information is stored in line 114Ø as DATA.52,.48. You can reset this ratio by choosing any two positive numbers that total one.

For example, if you wish to examine the consequences of 25% male births and 75% female births, you would type:

```
114Ø DATA.25,.75
```

Remember to use decimal numbers and place the male number first. This should be done just before typing "RUN".

See also: "ADDITIONAL INVESTIGATION SUGGESTIONS" in *STUDENT MANUAL*, p.16.

IX. BIBLIOGRAPHY

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